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DEVELOP AND TEST FUEL CELL POWERED  
ON SITE INTEGRATED TOTAL ENERGY SYSTEMS:  
PHASE III, FULL-SCALE POWER PLANT DEVELOPMENT

19TH QUARTERLY REPORT: NOVEMBER 1985 - JANUARY 1986

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SECTION I. INTRODUCTION

Engelhard's objective under the present contract is to contribute substantially to the national fuel conservation program by developing a commercially viable and cost-effective phosphoric acid fuel cell powered on-site integrated energy system (OS/IES). The fuel cell offers energy efficiencies in the neighborhood of 40% of the lower heating value of available fuels in the form of electrical energy. By utilizing the thermal energy generated for heating, ventilating, and air-conditioning (HVAC), a fuel cell OS/IES could provide total energy efficiencies in the neighborhood of 80%. Also, the Engelhard fuel cell OS/IES, which is the objective of the present program, offers the important incentive of replacing imported oil with domestically produced fuel.

Engelhard has successfully completed the first two phases of this program. The culmination of the pre-commercialization program will be the integration of the fuel cell system into a total energy system for multi-family residential and commercial buildings. The mandate of the current Phase III effort is to develop a full-scale 25kW breadboard power plant module. An accomplished objective in Phase III was the integration and testing of the 5kW system whose components were developed during Phase II. In addition to the development and testing of this sub-scale system, scale-up activities have been carried out under Phase III. Throughout this program, continuing technology development activity will be maintained to assure that the performance, reliability, and cost objectives are attained.

## SECTION II. TECHNICAL PROGRESS SUMMARY

### TASK I - 5kW POWER SYSTEM DEVELOPMENT

The objective of this task was to complete integration of the 5kW components and sub-systems developed during Phase II.

Steady-load testing of the 5kW integrated system, with regular shutdowns, was completed during August 1983. Subsequently, load-following testing was carried out successfully, as the system was operated in the fully-automatic mode. This activity is summarized in the August-October 1983 Quarterly Report.

### TASK II - ON-SITE SYSTEM APPLICATION ANALYSIS

The purpose of this task was to develop an application model for on-site integrated energy systems. The model considers fuel availability, costs, building types and sizes, power distribution requirements (electrical and thermal), waste heat utilization potential, types of ownership of the OS/IES, and grid connection vs. stand-alone operation. The work of this task was carried out under subcontract by Arthur D. Little, Inc. (ADL), and this work has been completed. The main conclusions are summarized in the May-July 1983 Quarterly Report.

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## SECTION II - CONTINUED

### TASK III - ON-SITE SYSTEM DEVELOPMENT

This task forms the core of the Phase III contract effort. Work under this task will result in the breadboard design of a system for an on-site application. The power plant is being designed for a rated output of 25kW (electrical). This task is broken down into four sub-tasks as follows:

- III-1. Large Stack Development
- III-2. Large Fuel Processor Development
- III-3. Overall System Analysis
- III-4. Overall System Design and Development

The activities under this contract are focusing on Sub-Task III-1. Effort on the other sub-tasks is being carried out under private sponsorship.

### SUB-TASK 1. LARGE STACK DEVELOPMENT

#### A. LONG-TERM TEST STACKS

A key activity in the current program is long-term reliability testing of stacks incorporating state-of-the-art components and concepts. This effort will serve to verify their effectiveness and durability; alternatively, if problem areas (or potential problem areas) are exposed over the course of this program, modifications will be implemented as appropriate to attain long-term durability.

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## SECTION II - CONTINUED

This phase has consisted of the construction, testing and evaluation of 4kW, 13 inch x 23 inch stacks. The first two stacks were essentially the same, each incorporating both the E-3 type and E-7 type of developmental cathode catalysts. Much of the testing utilized synthetic reformat fuel (75% H<sub>2</sub>, 24% CO<sub>2</sub>, 1% CO, moisturized to about 15% H<sub>2</sub>O). These 25-cell stacks were shut down after operating for about 7000 and 8400 hours on load, respectively.

Stack No. 3, which contains 24 cells of the 13 inch x 23 inch size, has been on load about 1600 hours. Performance is currently 0.64 volts per cell on average at 161mA/cm<sup>2</sup> with the stack temperature ranging between 181°C and 191°C. A stack voltage versus time plot is shown as Figure 1. One cooling plate interface showed an erratic IR-drop during December. This was traced to the inadvertent use of a K-element pair with undersized groove depths. The stack was shut down for one day to allow disassembly and rework of these elements; it was then reassembled and returned to load.

The new technology features incorporated into this stack are being monitored in relation to the corresponding standard features. Cells in the six-cell sub-stack with alternative acid-transport layers are outperforming those in other sub-stacks thus far (see below), while the voltage loss at the bottom current collector, which is based on gold-clad wire, is now well below 10mV at 161mA/cm<sup>2</sup>; this is easily in conformity with the established goal (25mV maximum) and superior to the performance of other configurations in prior stacks after the same period of time, as shown in Figure 2. The temperature

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## SECTION II - CONTINUED

spread among the interior cells of the stack is only about 7°C despite the fact that six-cell sub-stacks (between cooling plates) are being used, instead of the previous five-cell sub-stacks.

### B. 25kW STACK

The 25kW stack components are based primarily on those that were successfully employed in the first two 4kW (25-cell) stacks (above). Where appropriate in light of experimental results obtained on the smaller stacks, design modifications were implemented for the 25kW stack. These involved acid collection/drainage means to avoid corrosion at the bottom of the gas manifolds and a 0.0015 inch thick gold foil layer at the bottom current-collecting plate interface, also to avoid corrosion as well as the buildup of interfacial IR-loss.

Recent testing of the stack has consisted of diagnostic evaluations using bottled hydrogen fuel. Since the reformer is apparently now ready to be recommissioned (see below), continuous testing using steam-reformed methanol fuel will resume in early February.

### C. 25kW SUPPORT SYSTEMS

The methanol reformer catalyst was replaced (after confirmation of contamination), reduced, and put back in operation during January. The load has been gradually increased; and currently, at a load of 22kW equivalent, methanol conversion is essentially complete (>99%).

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## SECTION II - CONTINUED

### TASK IV - STACK TECHNOLOGY

The purpose of this task, which will continue throughout the contract, is to investigate new materials and component concepts through bench-testing and stack trials. The criteria for selecting activities under this task are the prospects for improved performance, reduced costs, or improved reliability. Improvements in the performance of electrocatalysts, generated under Engelhard-sponsored Task VI, are reported under Task IV.

#### A. PERFORMANCE OPTIMIZATION

##### ALTERNATIVE ACID-TRANSPORT LAYERS

Additional evaluation of alternative acid-transport layers has been conducted in single-cells. This effort is directed toward reducing cell IR-loss as well as replacing the currently-used Kureha carbon fiber paper, which is no longer available in its present form. Currently, evaluation is being carried out in stacks. This will facilitate meaningful assessment of alternative configurations by providing realistic conditions of compressive load and acid replenishment as well as by allowing large areas of material to be tested at the same time.

A five-cell, 10.7 inch x 14 inch stack was constructed during October with an alternative acid-transport layer configuration (see Appendix). Two of the five cells have shown significant performance loss, while the remaining three cells have



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## SECTION II - CONTINUED

sustained essentially constant performance over about 2300 hours on load. The overall performance history to date is illustrated in Figure 3.

The results to date suggest that the alternative acid-transport layer configuration has the capability for improved cell performance; the average cell IR-loss is about 37mV at 161mA/cm<sup>2</sup>, about 15mV below the typical value in stacks, while the average cell open-circuit voltage exceeds 0.9V. However, it is also apparent that processing conditions are not yet consistent enough to yield uniform behavior.

This acid-transport layer configuration is also being tested in one six-cell sub-stack of 4kW Stack No. 3 (see above). These cells are thus far exhibiting a strong performance advantage over those in other sub-stacks, as shown in Figure 4. In this case the performance levels of the various cells of the six-cell sub-stack are quite uniform (within a 10mV range).

### B. COST REDUCTION

#### CURRENT COLLECTORS

Corrosion testing of Engelhard-fabricated gold-clad base metal wire, the basis for a less expensive current-collecting plate, continues to show no sign of phosphoric acid penetration through the gold cladding after seven months of immersion at 200°C.

A current collector assembly based on this type of wire has been incorporated into 4kW Stack No. 3 (see above.)

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## SECTION II - CONTINUED

### BIPOLAR PLATES

Lower cost graphite materials are being evaluated for possible use in bipolar plates. A material designated "PH" supplied by the SERS Division of Pechiney S.A. was tested for corrosion characteristics; also, ABA-type bipolar plates fabricated using this material were tested for through-plane gas leakage and electrical resistance. The corrosion tests showed PH to be superior to both graphite materials previously used ("HLM" from Great Lakes Carbon and "940G" from Airco-Spear). Figure 5 shows the respective corrosion currents at 0.8V versus RHE, while Figure 6 illustrates the corrosion current as a function of potential. A lower "Tafel" slope of the PH material is apparent from Figure 6; this indicates that the advantage of this material from a corrosion resistance standpoint would be even greater at typical fuel cell operating potentials (i.e., about 0.7V).

ABA-type plates comprised of PH graphite bonded with PFA Teflon film showed an ohmic loss of less than 2mV at 161mA/cm<sup>2</sup>. Gas permeability at room temperature was not detectable.

### C. RELIABILITY

#### CARBON SUPPORTS

The assessment of more corrosion-resistant cathode carbon support materials has shifted to Gulf Acetylene Black (GAB), which is intended as a replacement for the obsolete

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## **SECTION II - CONTINUED**

Shawinigan Black. Cathodes using E-3 catalyst on GAB are being tested in single-cells. One cell showed a peak performance of 0.711V IR-free (161mA/cm<sup>2</sup>, 191°C, H<sub>2</sub>-air) after about 600 hours, but it is evident that optimum electrode structure has not yet been achieved with this catalyst. Performance was 0.686V (same conditions) at shutdown after about 2650 hours on load.

### **LIFE TESTING IN SINGLE-CELLS**

A fixture in which the aluminum body is replaced by Type 316 stainless steel is being used in single-cell testing; this is expected to allow more meaningful long-term tests to be conducted without the complicating effects of fixture corrosion. This fixture has shown no sign of corrosion after a test of 1800 hours duration and two additional, shorter-term runs.

### **TASK V - FUEL PROCESSING SUPPORT**

The intent of this task was to provide background data and information to support the design and construction of an optimized 50kW fuel processor under Task III. Most of the effort of this task was devoted to screening and longevity testing of catalysts for steam-reforming of methanol. This task is now complete.

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## SECTION II - CONTINUED

### TASK VI - IMPROVED ELECTROCATALYSTS

Developmental electrocatalyst formulations are being prepared under Engelhard sponsorship. These are provided to the main program, and results are reported under Task IV.

Development is being pursued on both cathode and anode catalysts and supports; however, the major activity at the present time is directed toward improved cathode stability and activity (see Task IV).

SECTION III - CURRENT PROBLEMS

None .

SECTION IV - WORK PLANNED

TASK III - ON-SITE SYSTEM DEVELOPMENT

- Resume testing of 25kW integrated system.
- Continue testing of 4kW Stack No. 3.

TASK IV - STACK TECHNOLOGY

- Continue evaluation of alternative acid-transport layers in small stacks.

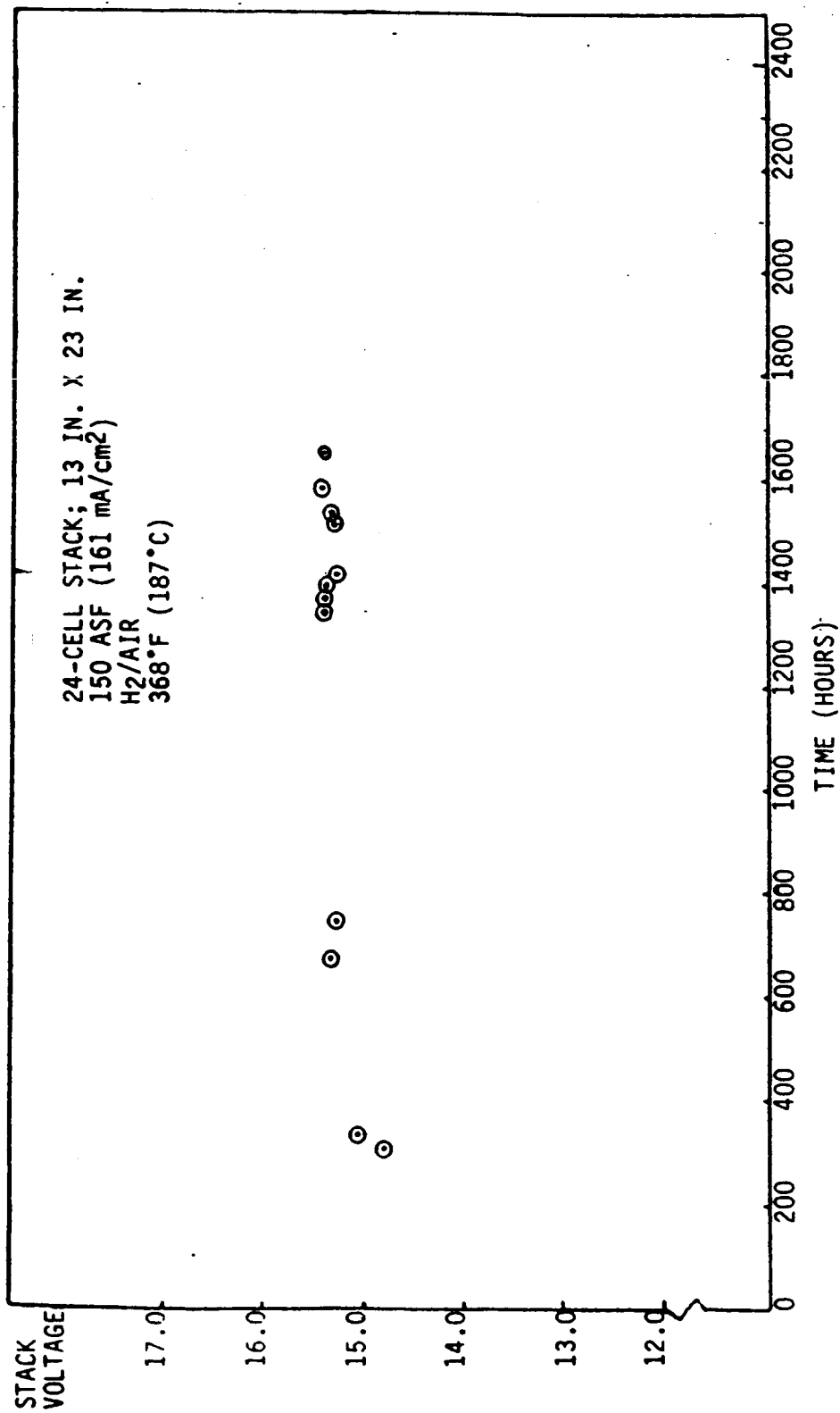


FIGURE 1      PERFORMANCE OF 4kW STACK NO. 3

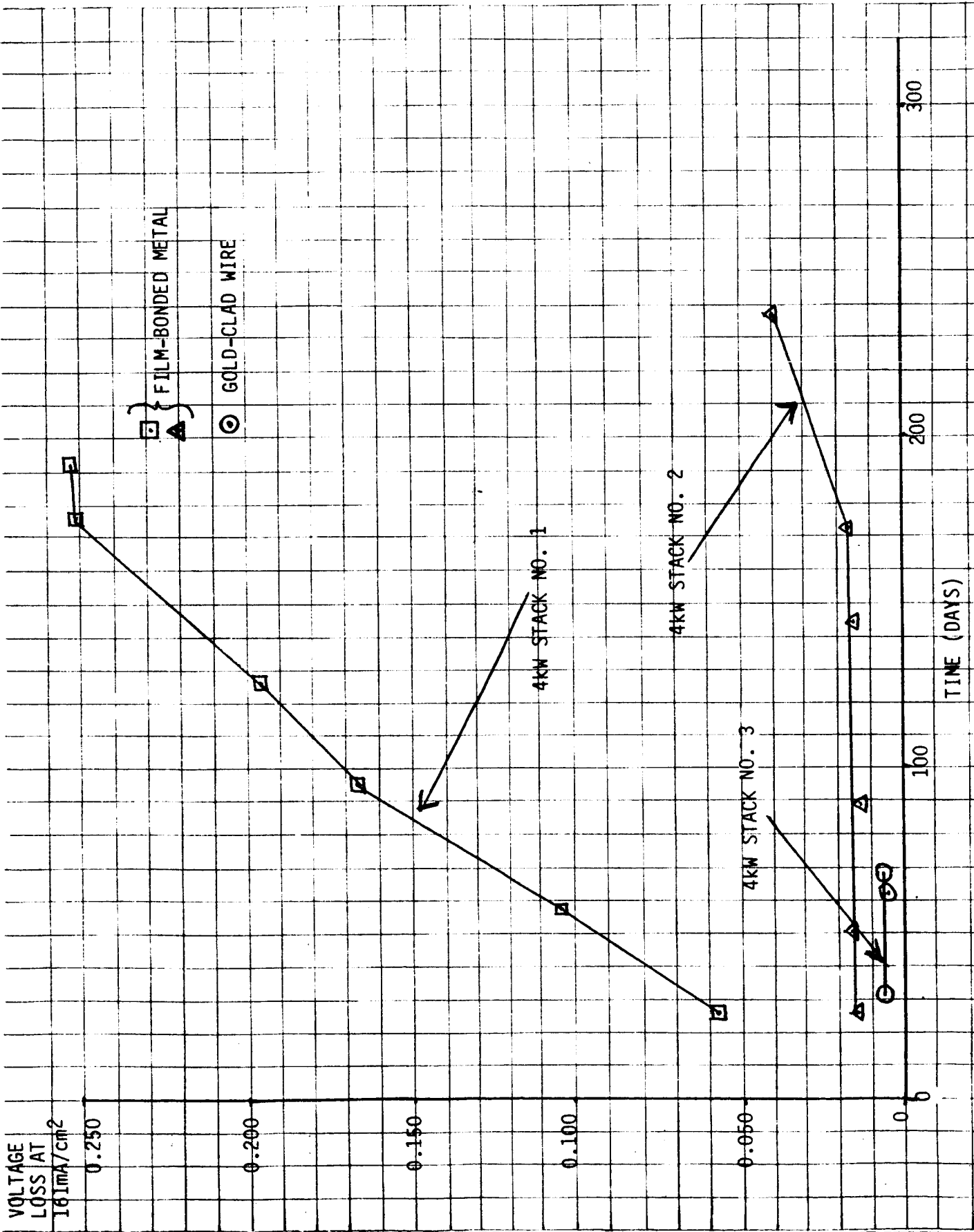
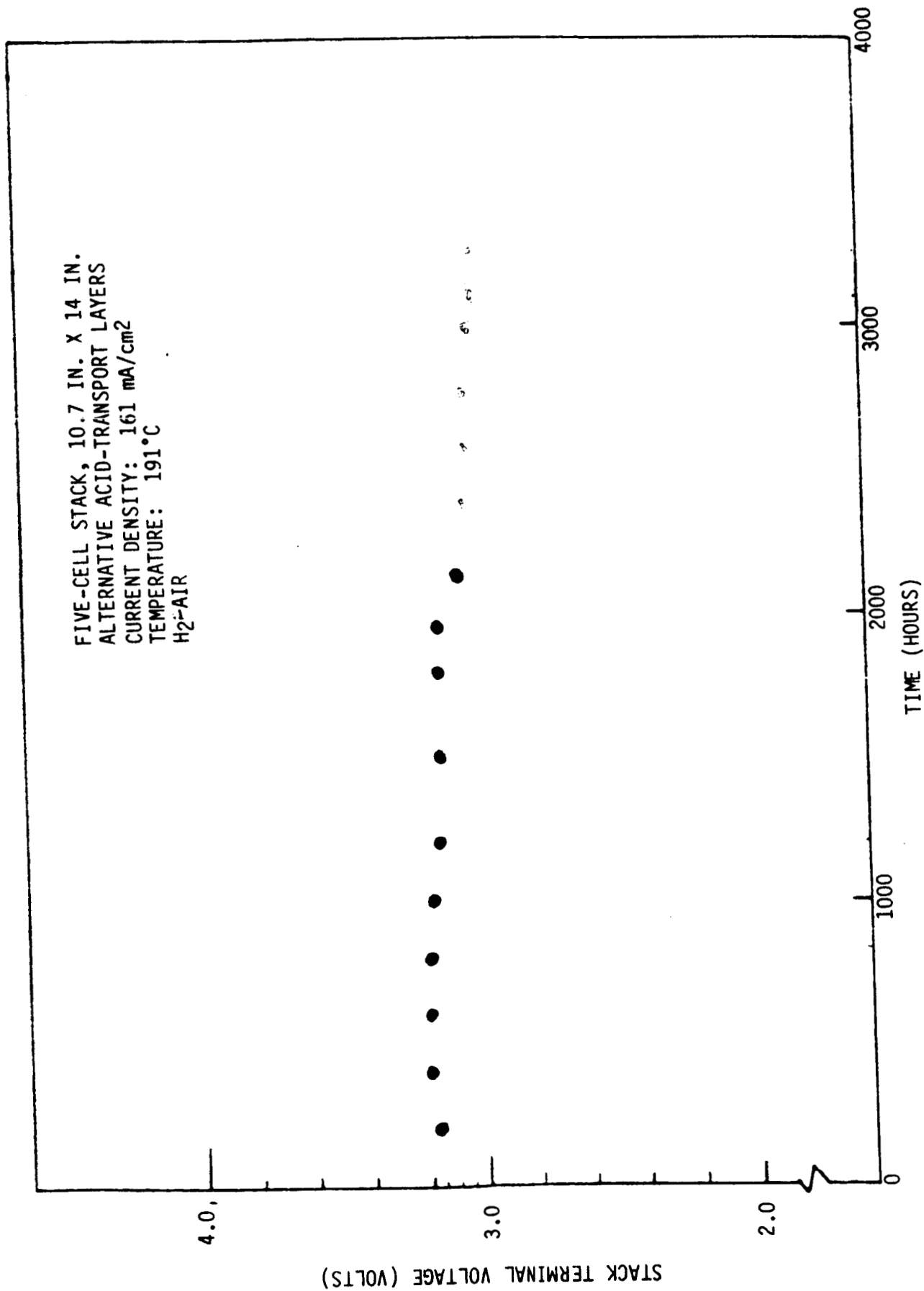


FIGURE 2 VOLTAGE LOSS AT BOTTOM CURRENT COLLECTOR VS. TIME



**FIGURE 3** PERFORMANCE STABILITY OF FIVE-CELL STACK WITH ALTERNATIVE ACID-TRANSPORT LAYERS



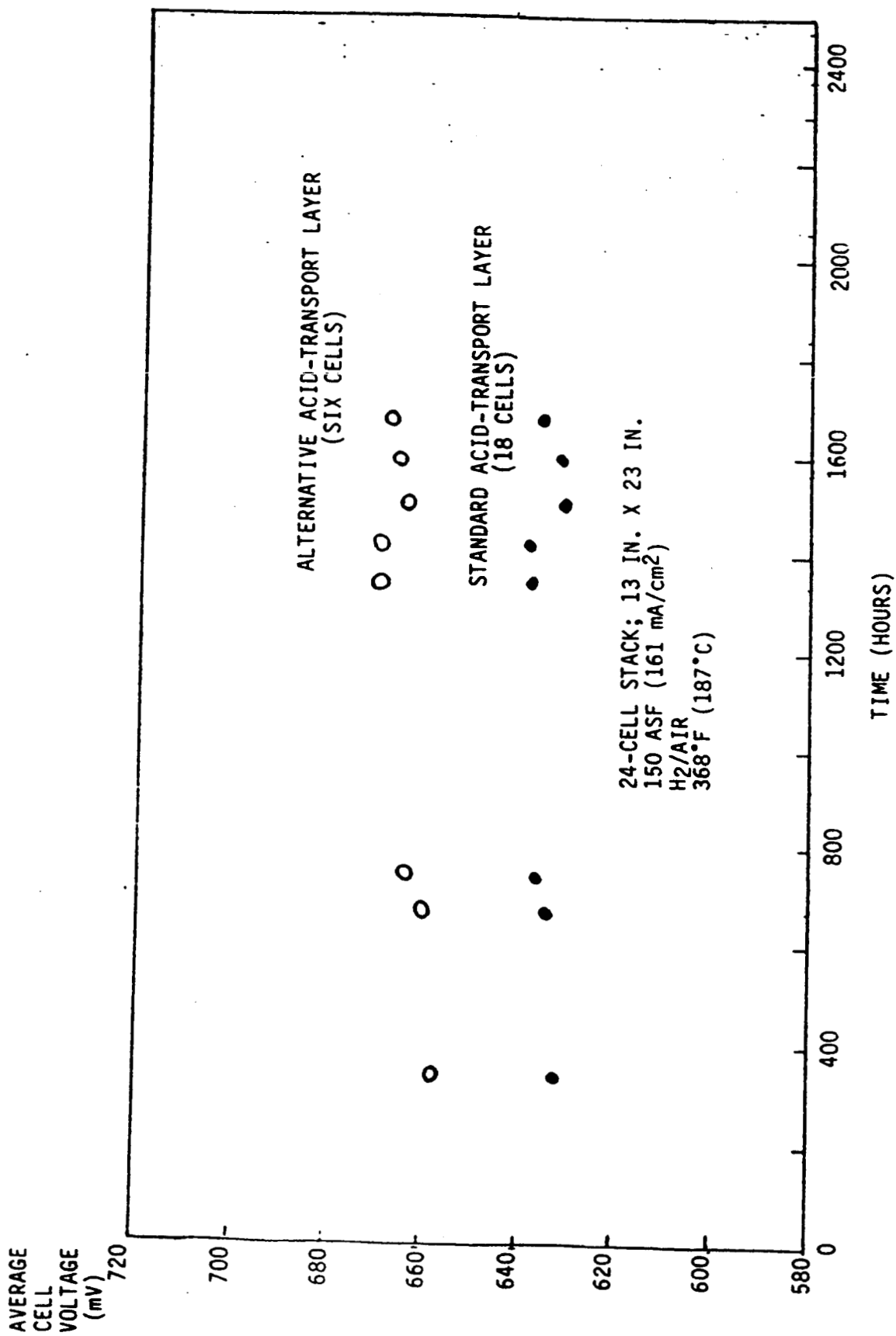


FIGURE 4 PERFORMANCE COMPARISON IN 4kW STACK NO. 3

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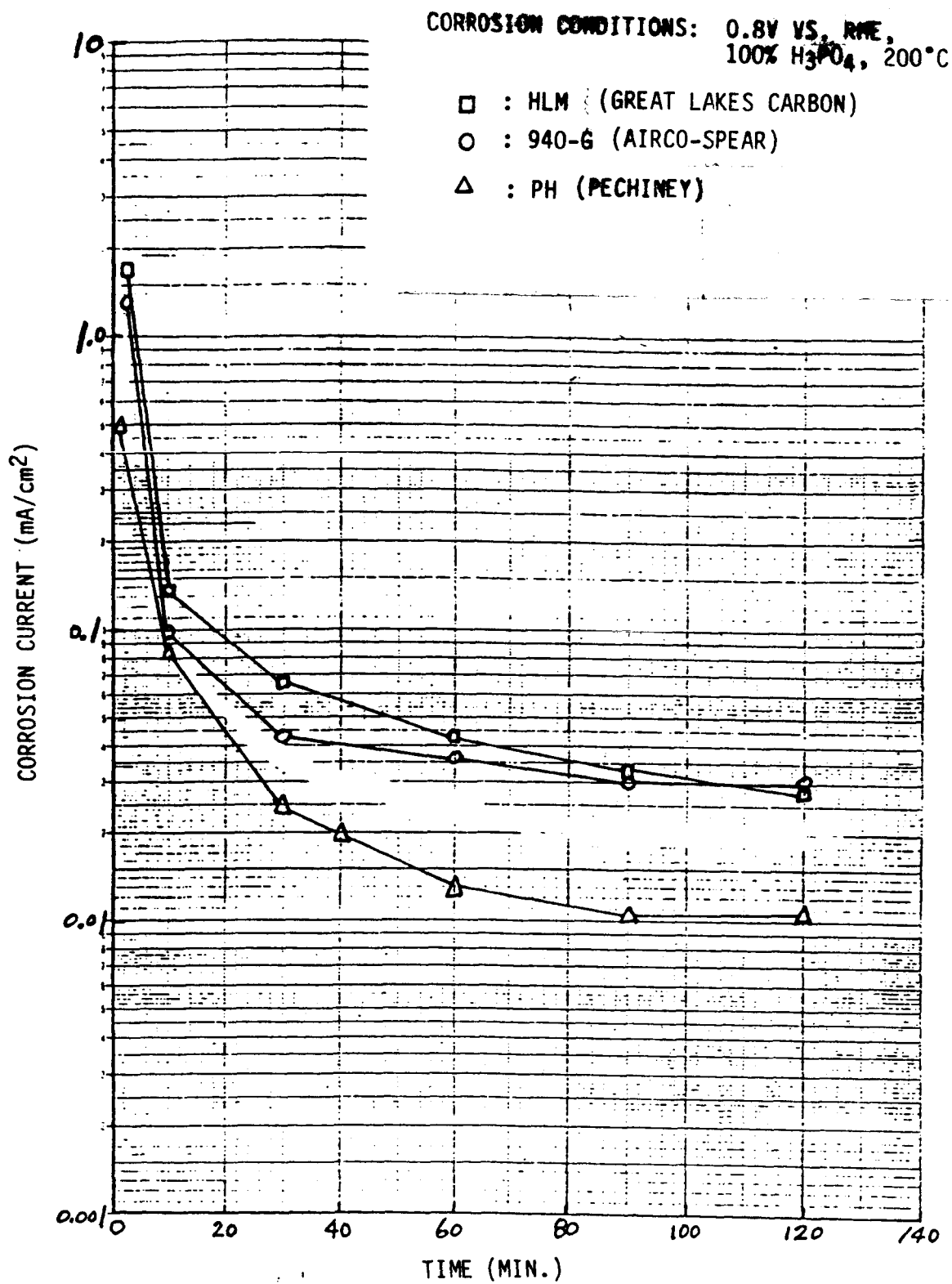


FIGURE 5

CORROSION CURRENT OF GRAPHITE PLATES

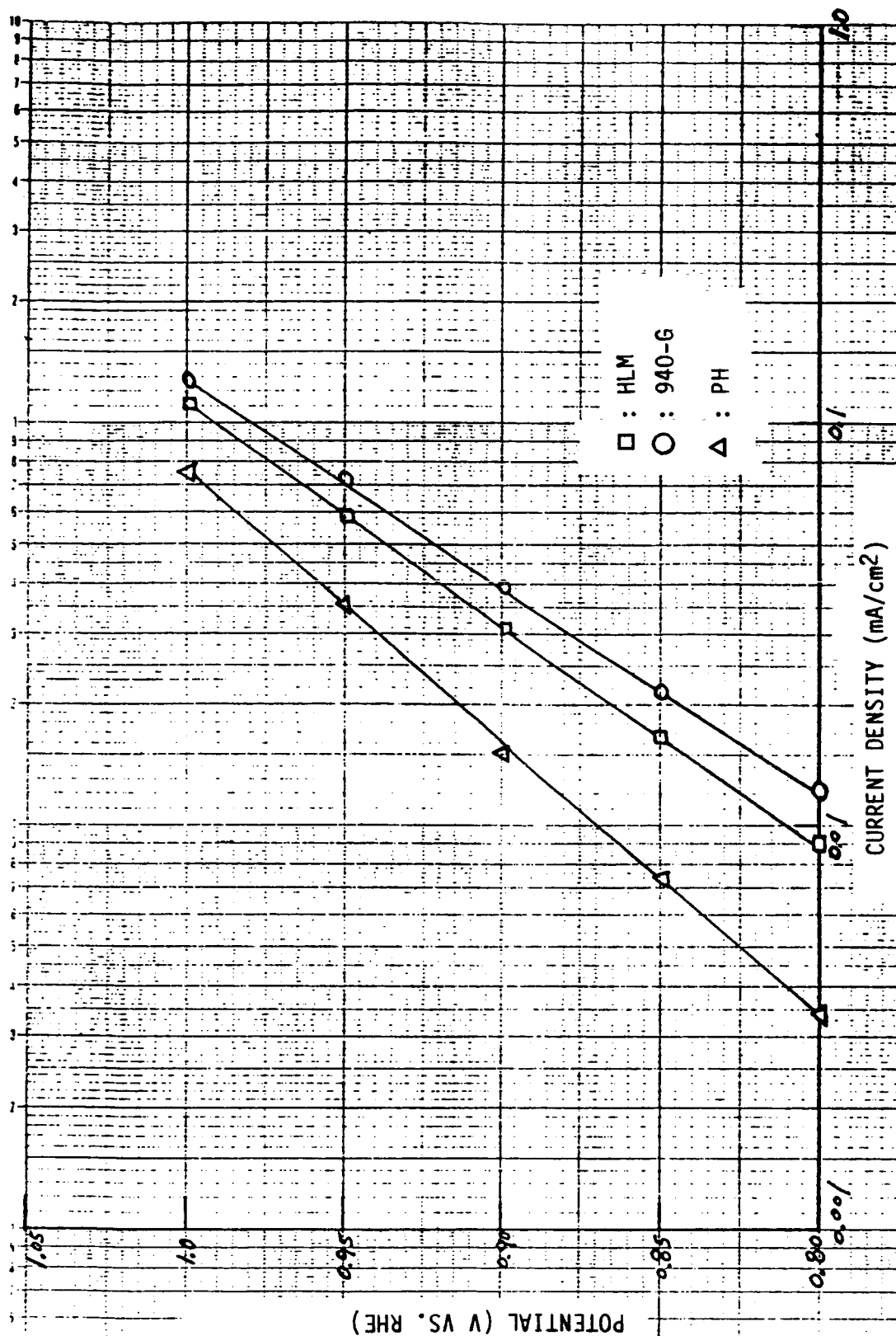


FIGURE 6 TAFEL PLOTS OF GRAPHITE PLATES AFTER 1000 MIN.

AT 0.8V (VS. RHE), 100% H<sub>3</sub>PO<sub>4</sub>, 200°C

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16. Abstract

The third in a series of 4kW stacks, consisting of 24 cells of the 13 inch x 23 inch cell size, has been on test for about 1600 hours. This stack is similar to the first two stacks, which ran 7000 and 8400 hours, respectively. The present stack incorporates technology improvements relating to the electrolyte-matrix, the current-collector assembly, and a reduction in the number of cooling plates. Performance is currently averaging about 0.64V per cell at 161 mA/cm<sup>2</sup>.

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